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HYDROMECHANICS

PROPELLER VORTEX CAVITATION INCEPTION STUDIES

by

John M. Coon

AERODYNAMICS

STRUCTURAL
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HYDROMECHANICS LABORATORY
RESEARCH AND DEVELOPMENT REPORT

APPLIED
MATHEMATICS

March 1963

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Report 1724

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S-R009-01 01

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NOTATION

$b_{0.7}$	Width of blade at $r/R = 0.7$
D	Propeller diameter
H	Propeller head at shaft centerline less vapor pressure
J	Speed coefficient, V/nD
n	Revolutions per unit time
P	Pitch
R_e	Reynolds number, $b_{0.7} \frac{\sqrt{V^2 + (0.7 \pi nD)^2}}{V}$
r/R	Dimensionless radius
V	Speed of advance
ν	Kinematic viscosity
ρ	Mass density
σ	Cavitation index, $H/(\rho/2) V^2$

ABSTRACT

Three TMB propellers were tested to determine the effect of pitch distribution on hub cavitation inception. Three fairwaters of varying geometry were also evaluated for their effect on inception of this type of cavitation. Observation of inception speeds on tip-vortex cavitation were also made.

The propellers tested in the 24-inch variable pressure water tunnel were TMB Propellers No's. 2963, 2964, and 2965. Fairwater geometries evaluated were 5 deg diverging and 5 deg converging truncated cones, and a conventional ogive configuration. The tests were performed at several cavitation indices over a range of speed coefficients.

It was found that reduction of the pitch at the tip delayed tip-vortex cavitation inception, whereas inception at the hub occurred earlier. Hub-vortex cavitation inception was delayed the most when the 5 deg diverging conical fairwater was used.

INTRODUCTION

One of the most effective means for delaying the inception of tip-vortex cavitation on marine propellers is to reduce the loading toward the tip of the propeller blades.¹ In order to maintain the desired thrust it is then necessary to shift the loading toward the hub. It was suspected that this shift of the loading toward the hub would increase the strength of the hub vortex and some preliminary experiments some years ago confirmed this. However, at that time the only test facility available for the study was the 35-horsepower propeller dynamometer which could be operated backwards in the towing basin. Cavitation tests in the basin, however, are limited

¹ References are listed on page 4.

by the fixed pressure and by the lack of any good method for observing the propeller. An upstream shaft had been proposed for the 24-inch water tunnel but it was not installed until 1961.

After this upstream shaft became available it was decided to conduct systematic tests to determine the effect of pitch distribution on hub-vortex cavitation. At the same time, it was decided that some nonconventional fairwater forms would be tested to determine what effect they might have in delaying the inception of hub-vortex cavitation.* This work was performed as part of the Hydromechanics Fundamental Research Program, Sub-project No. S-R009 01 01.

APPARATUS AND TEST PROCEDURE

The investigation of the model propellers and fairwaters was conducted in a uniform flow field in the TMB 24-inch water tunnel. A 4-horsepower dynamometer on the upstream shaft was utilized for thrust and torque measurements. Water velocity was measured with a pitot-static tube mounted in the plane of the propeller. Throughout the test the velocity was maintained at 15 ft/sec and the rpm was varied to give a range in speed coefficient J from 0.8 to 0.95. The Reynolds number varied from 1.2 to 1.4×10^6 . For the range of test conditions the tunnel pressure was varied and cavitation inception was recorded on the basis of visual observations at the condition where cavitation was no longer visible.

The three destroyer type propellers tested were designed to produce the same thrust at the same speed of advance and revolutions per minute. These propellers, Models 2963, 2964, and 2965, have four blades and are 8 inches in diameter with a hub diameter ratio of 0.20 and a P/D at 0.7 radius of 1.05. NACABS (modified NACA 66 section, NACA meanline $a = 1$) sections were used. Propeller 2963 was designed for constant pitch, whereas Propellers 2964 and 2965 were designed for 10 percent and 20 percent pitch reductions at the tip, respectively, as shown in Figure 1. The three models were also designed for the blade sections to operate at a zero angle of attack at a speed coefficient of 0.84.

* Similar fairwater forms have been tested at the Ship Laboratory of the National Research Laboratories, Ottawa, Canada

The three propellers were first tested with the ogive fairwater, and hub and tip-vortex cavitation were observed and inception conditions recorded. To determine the effect of fairwater geometry, one propeller, Model 2964 was then tested with the 5 deg diverging and 5 deg converging fairwaters. These fairwaters were truncated cones, two hub diameters in length, and are shown in Figure 5.

RESULTS

The data from the tests were reduced to dimensionless coefficients, and the cavitation indices for inception were plotted as a function of the speed coefficient, J .

Figure 2 shows the effect of pitch distribution on cavitation inception for the propellers when fitted with the standard ogive fairwater. Inspection of this figure reveals that a pitch reduction from Propeller 2965 to Propeller 2963 near the hub decreases the hub cavitation inception index for a given speed coefficient. Likewise, a pitch reduction from Propeller 2963 to Propeller 2965 at the tip decreases the tip cavitation inception index for a given speed coefficient. It will be noted that the cavitation inception indices of the tip for all three propellers are below those for all hub indices of the three propellers. Tip-vortex cavitation was not observed for Propeller 2965 because inception conditions were outside the range of the instrumentation.

Figure 3 indicates that with Propeller 2964, the 5 deg diverging fairwater resulted in the hub-vortex cavitation inception being independent of the speed coefficient over the range investigated. For the other two fairwaters, hub cavitation inception indices increased with decreasing speed coefficients. The results of these tests indicate that hub-vortex cavitation inception is delayed substantially for the divergent fairwater. Since tip-vortex cavitation was delayed with this propeller design, the limited range of test conditions imposed by the equipment permitted only a few inception conditions to be observed. No conclusions could be drawn regarding the effect, if any, of fairwater geometry upon tip-vortex cavitation.

The change in fairwater geometry appeared to have no effect upon the propeller thrust. However, the upstream shaft is somewhat sluggish and small changes in thrust could not be measured accurately enough to be reasonably certain there was no effect.

CONCLUDING REMARKS

For the propeller designs investigated it was found that, while reduction of pitch at the tip delayed the inception of tip-vortex cavitation, it led to earlier inception of hub-vortex cavitation. The use of a divergent truncated conical fairwater delayed hub-vortex cavitation considerably. Since these results are based only on one series of pitch distributions and one series of fairwater shapes, this investigation should be extended to include other propeller and fairwater designs. By designing for a load distribution which unloads the propeller blade near both the tip and the hub, it should be possible to delay both hub and tip-vortex cavitation inception.

ACKNOWLEDGMENT

The author is indebted to Mr. M. L. Miller for technical guidance during the course of this investigation.

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1. Bowers, W.H. and Fisher, R.E., "The Delay of Tip Vortex and Laminar Cavitation on Submarine-Type Model Propellers for Reduction of Pitch Near the Blade Tips," TMB Report C-58 (1947)

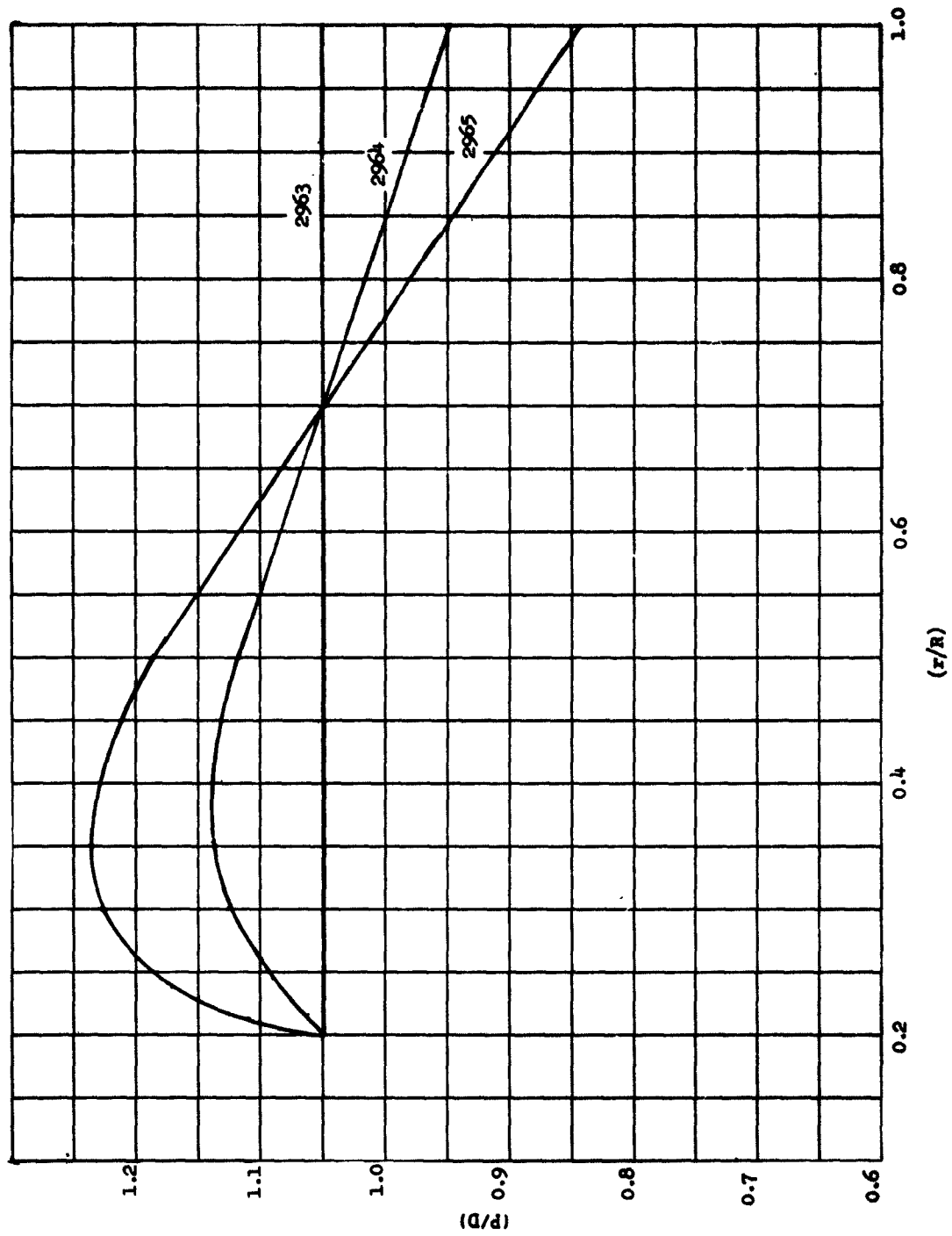


Figure 1 - Pitch Variation Curves of Propellers 2963, 2964, 2965

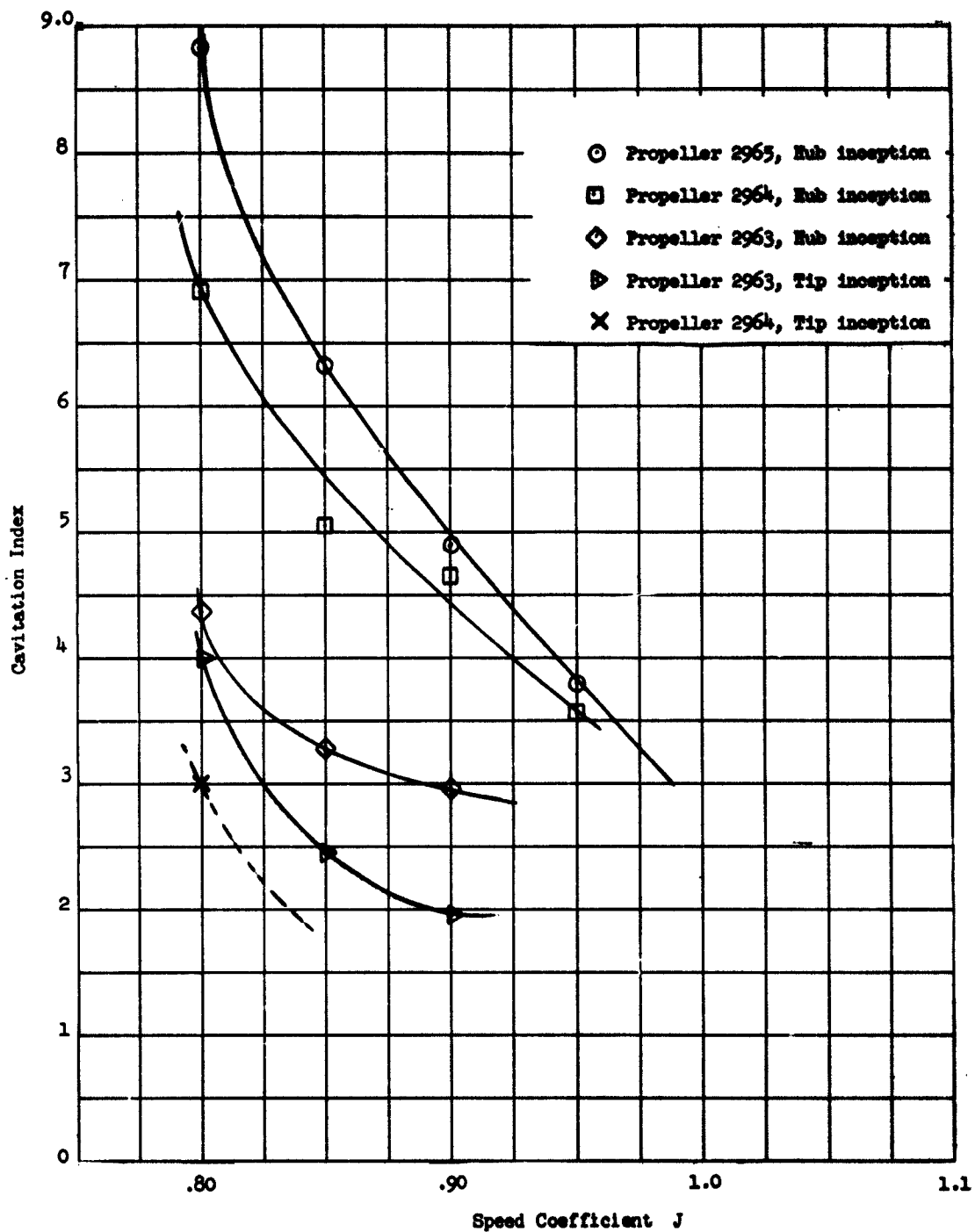


Figure 2 - Hub and Tip Vortex Cavitation Inception Curves of Propellers 2963, 2964, 2965

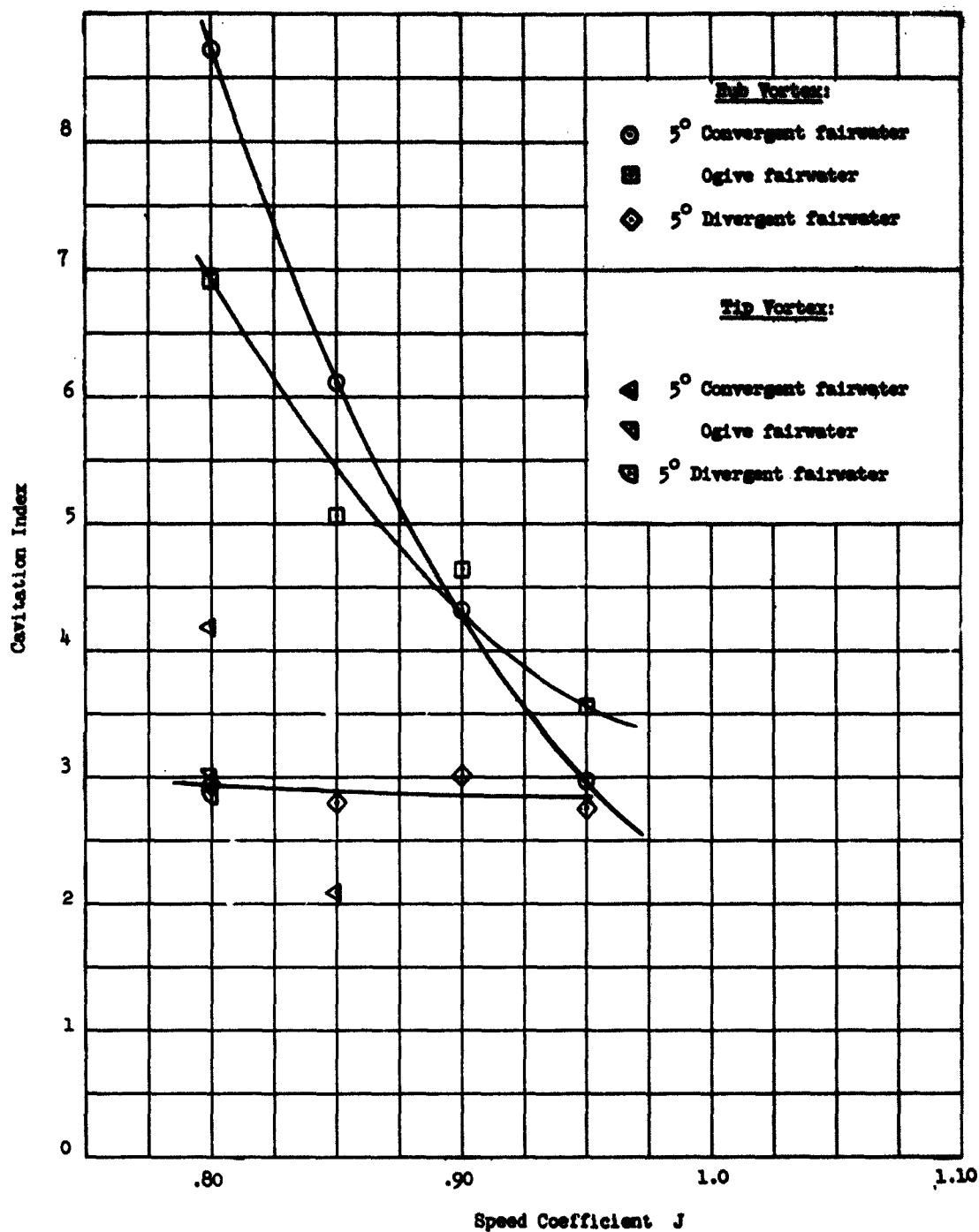
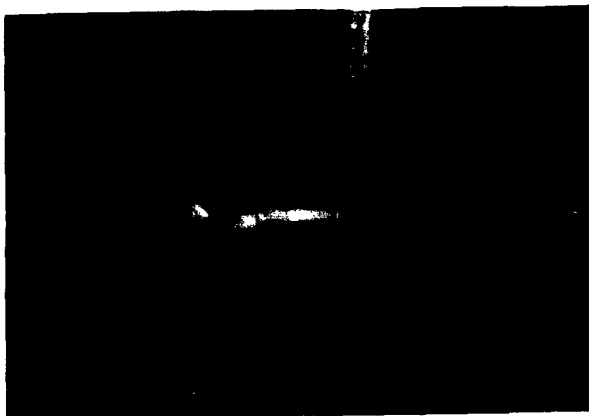


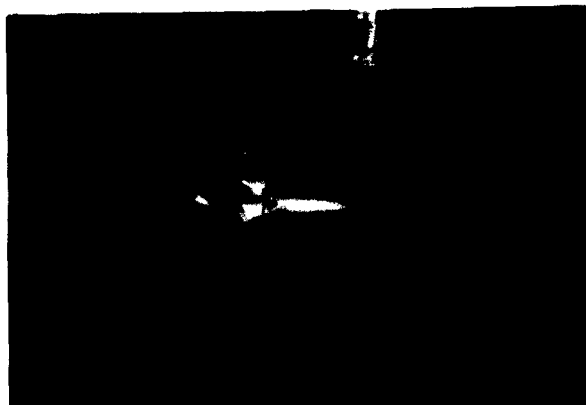
Figure 3 - Hub and Tip Vortex Cavitation Inception Curves of Propeller 2964 Fitted with Different Fairwaters



2963

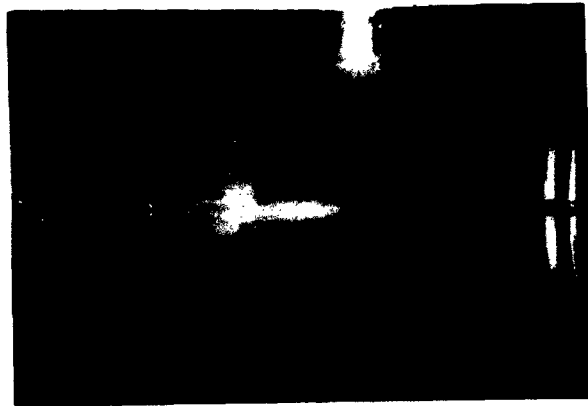


2964

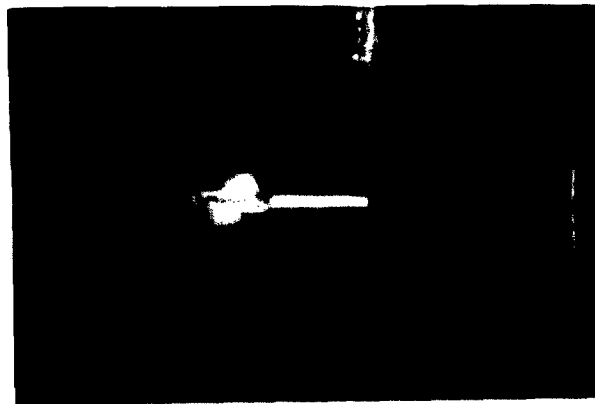


2965

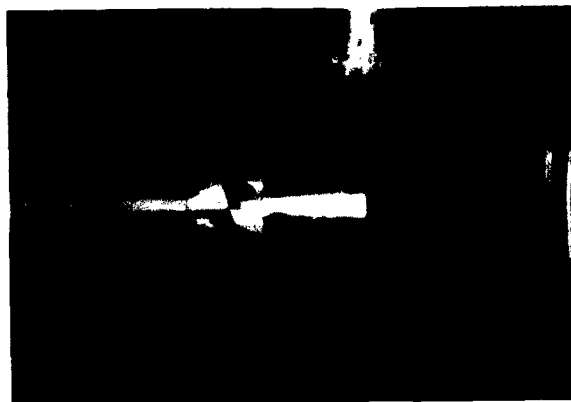
Figure 4 - Photographs Showing the Effect of Pitch Distribution on Cavitation



2964



2964



2964

Figure 5 - Photographs Showing the Effect of Fairwater Shape on Cavitation

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1. Propellers--Cavitation--Model Tests
2. Propeller--Hub vortex--Cavitation
3. Propellers--Tip vortex--Cavitation
4. Propellers--Fairwaters
5. Propeller models--Model 2963-2965

I. Coon, John M
II. S-R 009 01 01

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